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REPORT
NGR-03-002-219
September 15, 1972

Asteroids

In our program of photometry and polarimetry of selected asteroids Zellner is engaged in putting together definitive polarization-phase curves for Ceres, Pallas, Juno, and Vesta. The best available data (mostly unpublished observations by Gehrels) are being supplemented by new observations to fill the gaps in phase coverage and to reduce the observational scatter. The results to date are given in Figures 1 through 4. It is interesting to note that, in spite of substantial numerical differences, all four curves seem to show a very steep drop in polarization at phase angles less than 3°, followed by a broad flat minimum and a remarkably linear rise to positive polarizations. A deep negative branch is indicative of a dark, dusty surface; the physical mechanisms behind this characteristic shape, however, are still obscure.

We are especially interested in the asteroids that pass inside the orbit of Mars, since these are among the smallest, and hence probably the most nearly primordial, solar-system objects accessible to ground-based astronomy. Our experience gained during the 1968 close approach of Icarus (Gehrels, Roemer, Taylor and Zellner, Astron. J. 75, 186, 1970) has been invaluable for the current apparitions of Eros and Toro. For the first time, we are able to examine Mars-crossers at phase angles larger than 90° (Toro), and on the negative polarization branch at phase angles near 10° (Eros). An extensive campaign of observations at Mauna Kea in July and August, jointly supported by NGL 03-002-081, has been highly successful. The equipment has just returned to Tucson, the data are being processed. A TORO study meeting will be held in December with as participants: Alfvèn, Chapman, Danielsson, Goldstein, Torrence Johnson, Matson, Williams and a few others.

Radar Observations of Toro

Gehrels assisted Dr. Richard Goldstein of JPL during the nights of August 10 and 11, 1972, at the Goldstone 64-m dish for radar observations of Toro. A good return signal was obtained that, in comparison with Icarus in 1968, will allow detailed analysis.

Iapetus

Figure 5 gives our preliminary polarization results (Zellner, Ap.J. 174, L107, 1972) for Iapetus. This remarkable satellite is two magnitudes fainter at eastern than at western elongation. Dollfus had proposed that Iapetus is highly elongated and rotates not synchronously but with two-thirds the sidereal period of rotation about Saturn. However the polarization difference between the leading and trailing sides indicates an albedo difference by a factor of six, consistent with the amplitude of the lightcurve. The same conclusions have been reached from infrared radiometry of Iapetus at the University of Hawaii (Murphy et al. 1972). Thus, aside from its intrinsic

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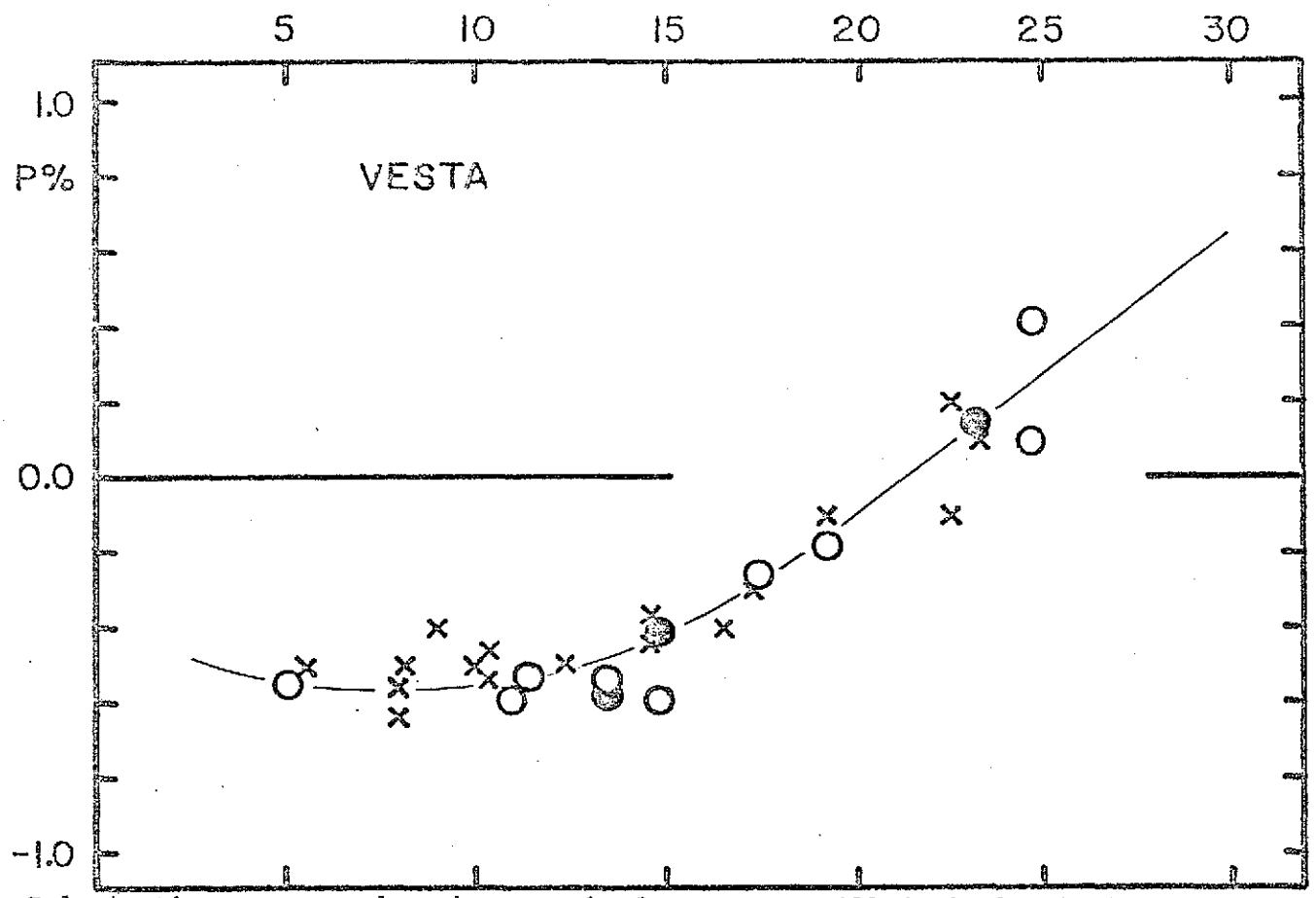

Fig. 1. Polarization versus solar phase angle for Vesta. Filled circles indicate data in blue light, open circles in green or yellow. The crosses are data points from Veverka (1970.

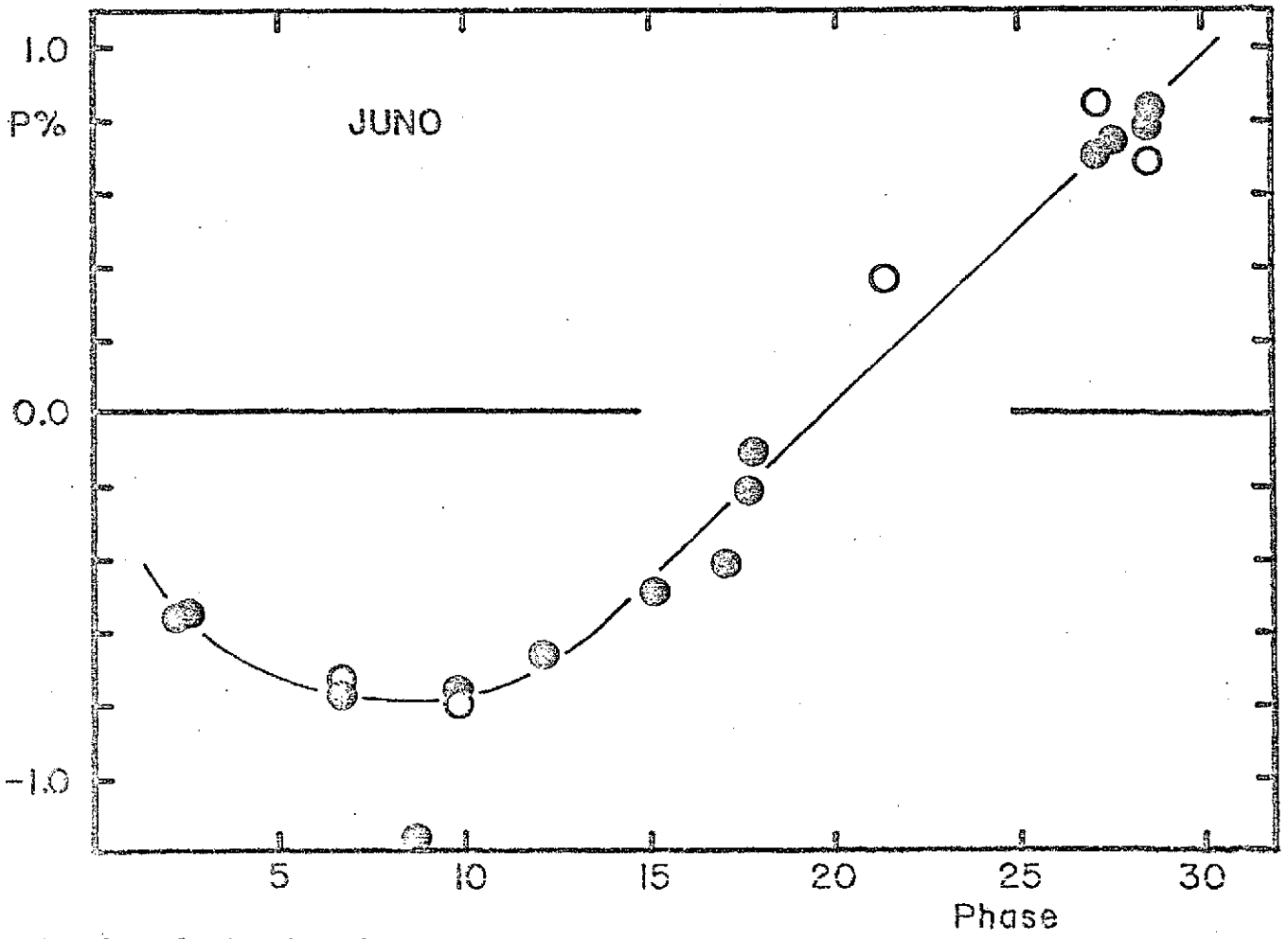

Fig. 2. Polarization observations of Juno. Symbols are as in Fig. 1.

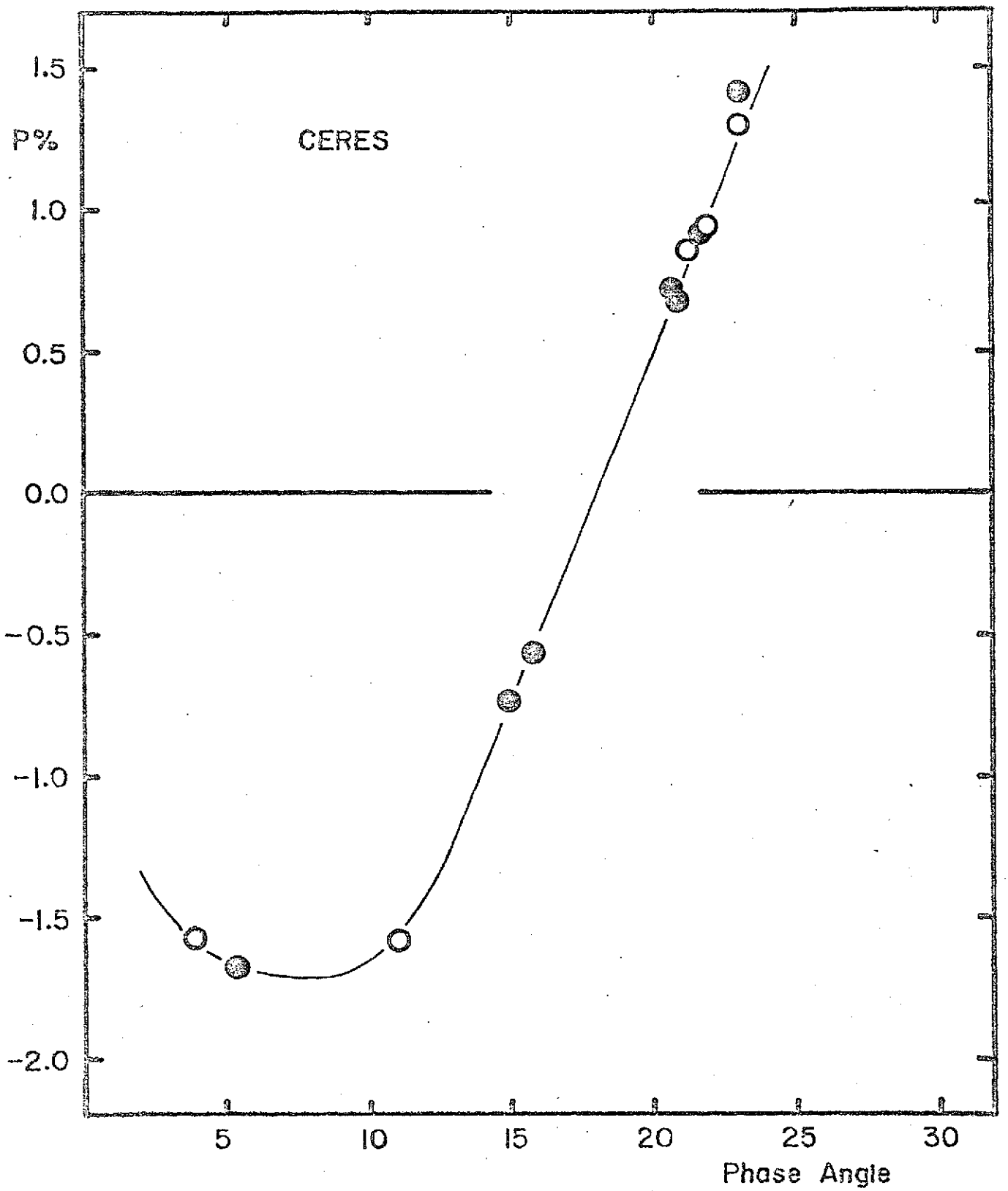

Fig. 3. Polarization observations of Ceres.

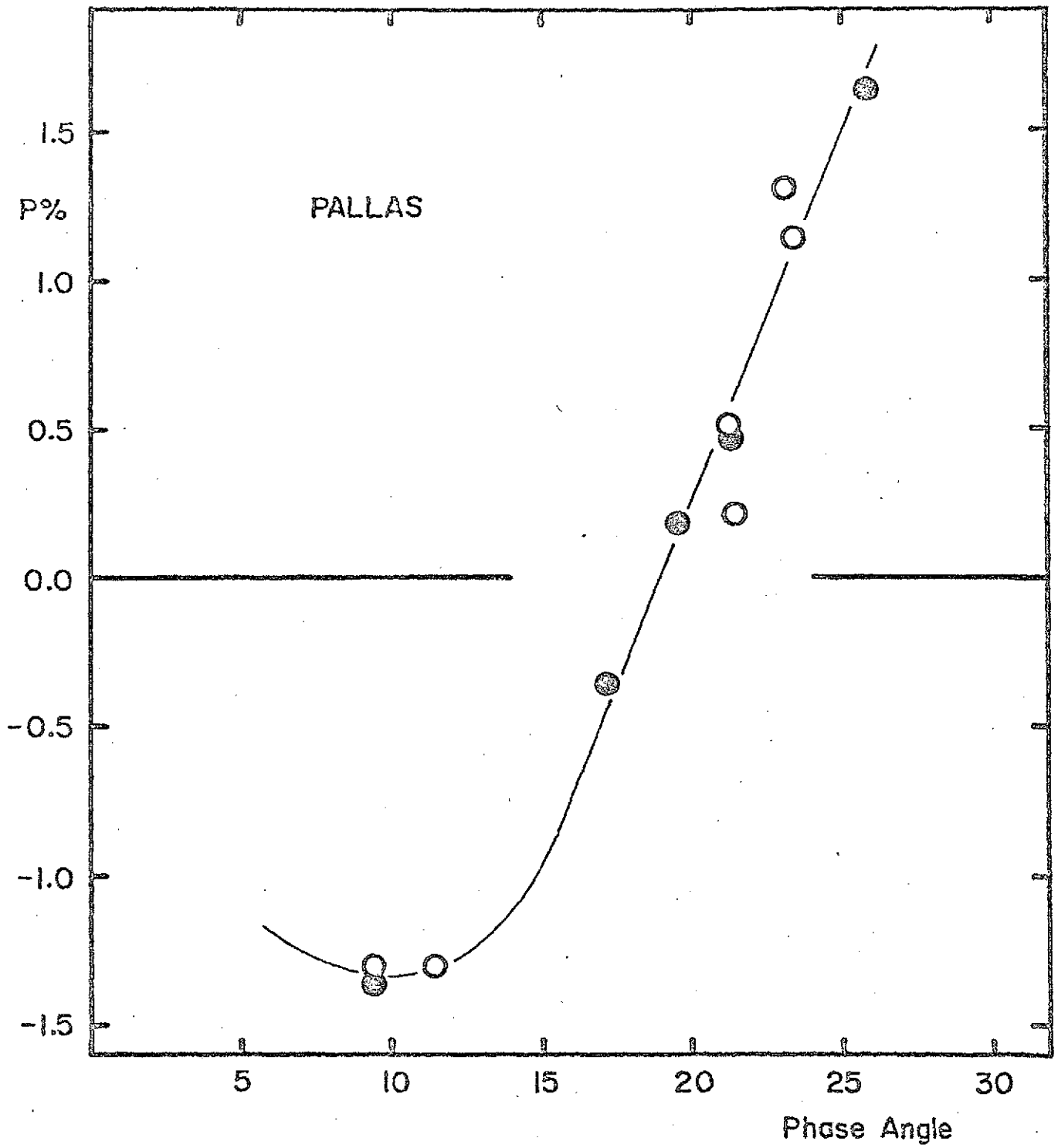

Fig. 4. Polarization observations of Pallas.

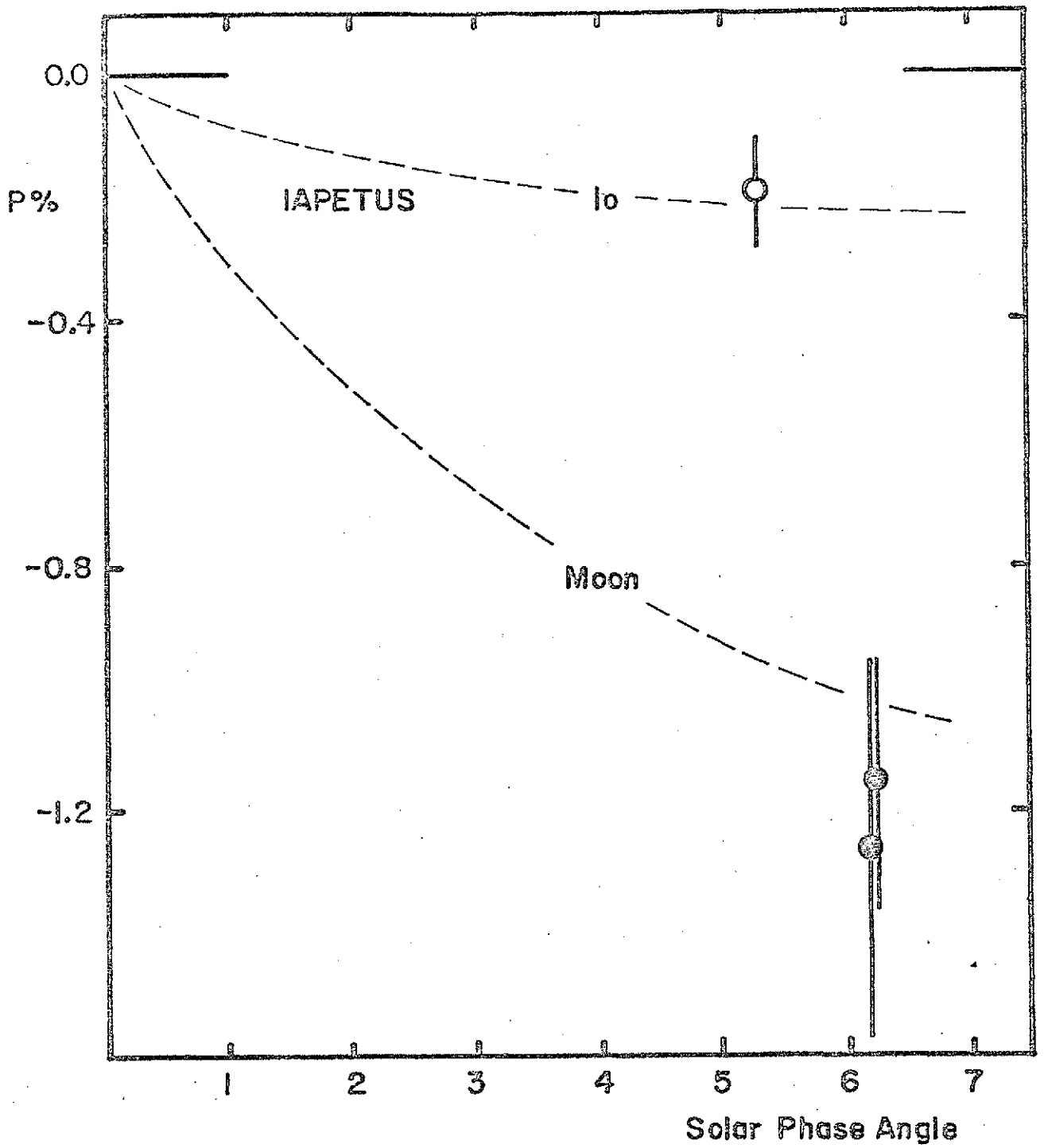

Fig. 5. Polarization of Iapetus in green light, from Zellner (1972b). Open circles indicate the trailing (bright) side, and closed circles the leading (dark) hemisphere. The polarization-phase curves of the Moon and Io are given for comparison.

interest, Iapetus provides an ideal "laboratory experiment" for the correlation between albedo and depth of the negative polarization branch for solar-system objects.

Our polarization data of the integrated disk of Mars were sent to Dr. Jayley Mead at Goddard Space Flight Center for interpretation. This material, comprising of over 500 measurements, is ready for publication pending the completion of our joint analysis. She has reported her procedure and initial results in an informal letter report as follows:

> My first efforts were to separate the polarization data by filter into predominantly light and dark regions (hopefully) by longitude based on de Vaucouleurs' photometric curve (Fig. 4 of "A Low-Resolution Photometric Map of Mars," Icarus 7, 310, 1967) in the hope that this would eliminate some of the scatter in the observations and that I could say something about the polarization of the light and dark areas. But the groups did not have enough points to be statistically meaningful or the criteria for calling a strip light or dark was not definitive enough. Next I made plots, always by filter, using special symbols for the time or position of the observation on the phase curve, i.e., before or after opposition or conjunction. No obvious groupings showed up in these plots either. Then I plotted the five telescopes with different symbols; they all seemed compatible.
>
> I compare Morozhenko's and Dollfus's polarization data with the Arizona material. The fit with the Russian data is surprisingly good except around 4450 (Arizona) vs. 4500 (Morozhenko); in this wavelength-region the Russian data showed higher values for the polarization at larger phase angles than did the Arizona observations. I do not know the characteristics of the filters used by Morozhenko, however, and this could explain some of the discrepancies.
>
> I have computed the percentage polarization for refractive indices of 1.20, 1.31, 1.35, 1.45, 1.55, 1.65, and 1.75 with various submicron particle size distributions. From these results the most promising materials, i.e., those which have a high positive polarization at phase angles between 15° and 40° are for n = 1.31 and 1.35 (H_2O and CO_2 particles possibly). The larger refractive indices give negative polarization for these phase angles, at least for the submicron size particles which I have considered.
>
> I am still troubled by the uncertainty of the surface contribution to the polarization, which we knew would be the difficult part. I can juggle various surface contributions, based on the polarization of the Moon and Mars at wavelengths between 0.55 and 1 micron, but I may be just playing games, which is not too satisfying. I am impressed with the similarity of the polarization for Mars and the Moon with the G and I filters (Gehrels et al., A.J. 69, 826, 1964) and the difference between the two when the U-filter is used; so I do think a good case can be made for the fact that the shorter-wavelength observations have an atmospheric contribution.

Preparations Polarization Meeting

The preparations for the Nov. 14-18 IAU Colloquium on Polarimetry are in full swing. Several members of our team are working on invited review papers: "Polarization of Planetary Surfaces without Atmosphere" by Zellner, "Introduction" and "Future Studies" by Gehrels, "Planetary Atmospheres" by Coffeen and Hansen, "Techniques in Optical Polarization" by Serkowski, "Polarization by Interstellar Grains" by Coyne, "Reflection Nebulae" by Zellner, "Intrinsic Polarization in Late-Type Giant and Supergiant Stars" by Shawl, and on contributed papers: "A New Method to Obtain Accurate Instrumental Polarization" by KenKnight, and "Polarimeters in Space" by Hämeen-Anttila. Gehrels is the coordinator for this meeting and he will be the editor of the book "Planets, Stars and Nebulae, studied with Photopolarimetry". Mrs. Mildred Matthews is the technical editor and assistant for many of the arrangements. It appears there will be some 120 participants at the meeting, about 60 papers in the book, and the book will be patterned after NASA SP-267 "Physical Studies of Minor Planets" in execution and scope which was to provide a source and reference book where none existed before.

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